PROPOSAL FOR FEASIBILITY STUDY OF

IONIC OSCILLATORS

by

An article in the December issue of Radio-Electronics titled, "The Ionic Oscillator" by the inventor, Thomas E. Fairbairn, is an elaboration on this device for which he was issued a patent in August, 1952. It is described as a new type of gas tube oscillator which contains no resistive, capacitive or inductive time constants, and needs no external or internal resonant circuits or cavities.

The article states that it will operate on as little as 2 milliamperes from a plate supply of $22\frac{1}{2}$ volts since the oscillations are generated in the ionized gas and not in an external circuit.

Gas tubes reported tested were listed as follows: 884 - 500 kc tunable from 400 to 1,000 kc; 6Q5 - 1,000 kc tunable from 500 kc to 1,500 kc; 2050 - 1,500 cycles tunable from 1 to 20,000 cycles; OC3/VR105 - 1,400 kc tunable from 900 to 1,900 kc. Navy SN7 stroboscope tube - 1,000 cycles tunable over entire audio range.

Three or more element tubes were modulated either in AM or FM arrangements with crystal or dynamic mikes or phono pickups.

[redacted] checked most of the work described above and found similar results in most respects. It was noted that the 884 ignited at 17 volts and dropped to 15 volts. It oscillated at about 500 kc with a sawtooth shaped wave, however, the addition of a 2K ohm resistor smoothed it out to a sinusoidal wave. At 800 kc it was quite noisy and also had a pronounced mechanical resonance at zero impedance. (The miniature version 6D4 responded in similar fashion.) The 2D21 used by the writer did not oscillate. STAT

OB2/105VR was very critical at 15 kc. It drew 8 microamps and at 50 kc, 36 microamps. With a 3.9 meg resistor it had a .7 volt peak to peak output. The critical range was between 20-25 microamps. It was a true high impedance device.

The inventor made an exception to certain neon tubes as being ionic oscillators, however, [redacted] were able to get the NE2 neon to oscillate between 5 and 20 kc. This was accomplished by using a high impedance of 3 to 5 meg resistance at 60 V. 6.5 kc at 5 microamps the pp voltage was .5 volts at 15.5 kc and 14 microamps the pp voltage was 2.7 volts. STAT

It was also noted that the frequency of the neon tube could be varied by heat or light.

The foregoing data, presented by Fairbairn and substantiated in most particulars by experiments conducted by [redacted] certainly STAT points to an intriguing, yet little known phase of electronics - the fact that the ionic oscillator needs no external coupling circuit and can transfer its output almost equally as well into a low or high impedance circuit is most noteworthy. In addition, it lends itself to duplicating various types of oscillator circuits now used and holds forth the eminent possibility that new arrangements might be made which would not only simplify present circuitry but point the way to miniaturization and economization of present day circuitry.

It is proposed that a contract be entered into with [redacted] STAT
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[redacted] to conduct a feasibility study of the present art of ionic oscillators and the associated phenomena of resonance in ionized gases.

This contract not to exceed $500.00 to cover salaries of search team as well as associated costs of supervisory coordination, interpretation of results and preparation of preliminary and final reports on the study.

THE IONIC OSCILLATOR

By THOMAS E. FAIRBAIRN

A patent* was issued August 19, 1952, on a new form of gas-tube oscillator which contains no resistive, capacitive, or inductive time-constants, and needs no external or internal resonant circuits or cavities. This new *ionic oscillator* can deliver high output at audio or radio frequencies and has good stability over long periods of time. This is the simplest electronic oscillator known, and operates on as little as 2 milliamperes from a plate supply of 22½ volts or less. Fig. 1 shows the ionic oscillator's simple circuit.

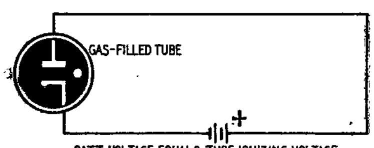


Fig. 1—The utter simplicity of the ionic-oscillator circuit. The battery voltage is made equal to the normal ionization drop across the gas tube.

The U.S. Naval Research Laboratory in Washington found that when a certain critical voltage is applied between the plate and cathode in an inert-gas or vapor-discharge tube, the ionized gas generates oscillations in the audio- or radio-frequency range. This is something like the oscillations in a resonating crystal—but with the added advantage of much higher output.

A very simple experiment convinced the Navy and patent men that the oscillations were generated *in the ionized gas* of the tube and not in any external circuits. Fig. 2 shows the basic circuit

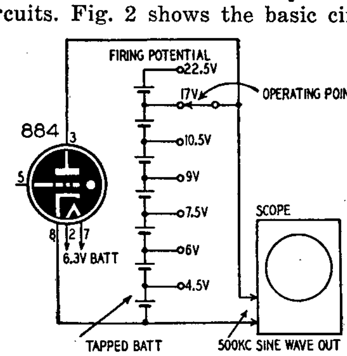


Fig. 2—Circuit used in original ionic-oscillator experiments. The full 22½ volts is applied first to fire the 884; then the voltage is reduced to the optimum value for stable sine-wave oscillations.

used in the experiment—nothing but an 884 thyratron, a 6-volt filament battery (a.c. can be used as well), a tapped 22½-volt B battery, and an oscilloscope connected across the plate-cathode circuit to show the output waveform. The physical setup is shown in the photograph. If you check the settings of the scope controls you can see that the frequency of oscillation of the 884 is about 500 kc.

This experiment showed that any gas-filled tube (except certain neon bulbs) will oscillate when you apply a d.c. voltage across its plate and cathode equal to the voltage drop of the tube when ionized, and it will generate an almost perfect sine wave (not a sawtooth as in other gas-tube oscillators). Many gas tubes besides the 884 were tested in the same circuit and they all oscillated in the same way, except that each tube had its own fundamental frequency of oscillation just as crystals have.

The ionic oscillator in this experiment put out enough r.f. to be picked up on a home receiver at distances of 10 feet or more—*without an antenna.*

The ionic oscillator can be tuned over a limited range by changing the plate-cathode voltage in diode types, or by inserting a variable resistor between plate and grid in triodes and adjusting it for the desired output frequency.

Some of the gas tubes tested and their fundamental single-frequency outputs are as follows: 884—500 kc, tunable from 400 to 1,000 kc; 6Q5—1,000 kc tunable from 500 kc to 1,500 kc; 2050—15,000 cycles tunable from about 1 cycle to 20,000 cycles; 0C3/VR105—1,400 kc tunable from 900 to 1,900 kc. The Navy SN7 stroboscope tube has an output of about 1,000 cycles tunable over the entire audio range. Neon bulbs have no frequency of oscillation as yet discovered. Fluorescent lights oscillate over a very broad frequency band and can be detected almost anywhere on the dial, but have definite peaks at certain frequencies. Some large thyratrons used in high-current circuits were found to have outputs as low as *8 cycles per minute,* with current changes of up to 1 ampere. Many other types of gas tubes were tested and frequencies as high as 9 megacycles were noted.

Modulation

Either frequency modulation or amplitude modulation may be applied, depending upon whether the modulating voltage is inserted in series with the plate or in parallel with the grid and cathode. A .01-volt a.c. signal applied between the grid and cathode of a triode-type gas tube as shown in Fig. 3 will modulate the output of the ionic oscillator from zero to well over 100 percent. (With over 100 percent modulation you get a pulse-modulated carrier.) A ±.01-volt input to the grid will produce as much as 1.5 volts change in the output carrier. This represents an a.c. amplification factor of 150, and also shows that grid control is possible with gas oscillators.

When a sound-powered or crystal microphone was connected between grid and cathode of the thyratron (Fig. 3) the voice-modulated output could be heard clearly on a radio receiver tuned to the fundamental frequency of the ionic oscillator.

When two ionic oscillators with different fundamental frequencies were connected in series as shown in Fig. 4 the result was a frequency-modulated carrier with an output of at least 1½ volts r.f. The percentage modulation of this series circuit could be varied with the 50,000-ohm control of the upper triode.

Advantages

Now let's look at the differences between this ionic oscillator and other more familiar oscillators. First we'll compare the ionic oscillator with the *relaxation* oscillator which also uses a thyratron (or a gas diode) and may confuse a person who is not up on his electronics. The relaxation oscillator

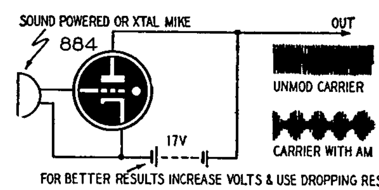
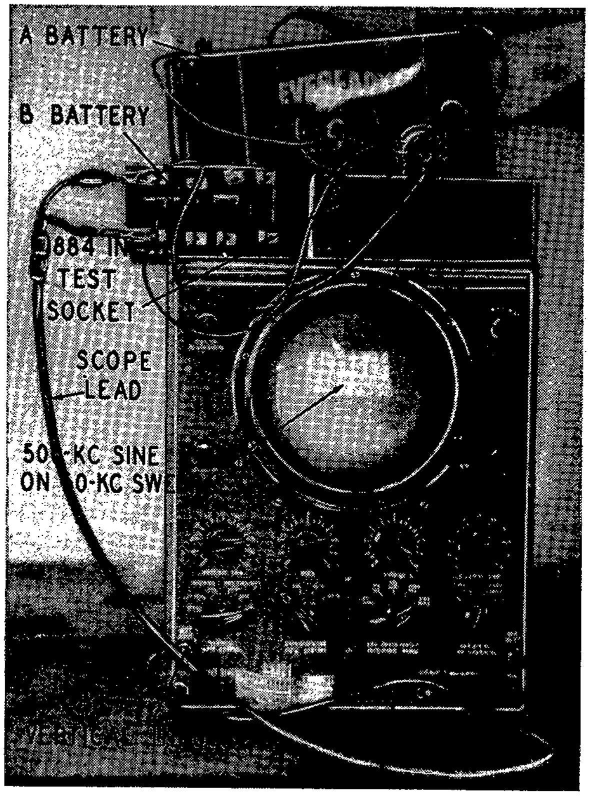


Fig. 3—Circuit of a voice-modulated ionic oscillator. The carrier frequency with an 884 is approximately 550 kc; with a 6Q5, approximately 1 mc.

gives out a *sawtooth* waveform, whereas the ionic oscillator gives out a sine wave. The relaxation oscillator has a top frequency limit of about 50 kc because of the electron transit time between the plate and cathode elements and the ionization and deionization time of the gas. The ionic oscillator has an upper limit of over 1,500 kc. In the relaxation oscillator an external R-C time-constant network sets the frequency of oscillation; but an ionic oscillator using the same tube type has nothing but a battery in the external circuit.

In the gas-tube relaxation oscillator the grid loses control over the output waveform once the oscillation starts, but in the ionic oscillator the grid maintains control at all times. This is proved by the voice-modulation circuit shown in Fig. 3. In addition, the ionic oscillator works at a voltage equal to the plate-cathode voltage drop of the

*U.S. patent No. 2,607,897



The physical setup of the circuit shown in Fig. 2. Sweep-control settings show the sine-wave oscillations have a frequency of approximately 500 kc.

ionized gas tube used, but the relaxation oscillator must have a much higher B supply due to the voltage drop in the external R-C network.

In comparing the ionic oscillator with the inductance-capacitance tuned-tank oscillator or the crystal oscillator, the ionic oscillator can be loaded very heavily; it needs no coupling circuit, and will transfer almost as much of its output to a low-impedance load as to a high-impedance load. In the L-C oscillator the resonant-tank circuit determines the frequency of oscillation, whereas in the ionic oscillator the ionized gas itself determines the resonant frequency regardless of the external circuit.

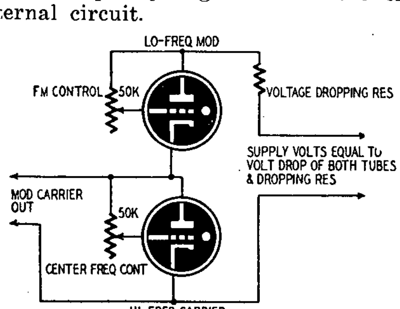


Fig. 4—An ionic-oscillator adapted to direct frequency-modulation.

One further advantage: An L-C oscillator can be detuned or killed by hand capacitance. The ionic oscillator is not affected at all.

In tuning an ionic oscillator the plate-cathode voltage is adjusted so that a small plate current flows. This current is fairly critical over a limited region for single-frequency operation. (With larger plate currents, the ionized gas oscillates erratically at random frequencies.)

A circuit for general experimental work is given in Fig. 5. Either an 884 or 6Q5 thyratron can be used. R1 is a variable voltage-dropping resistor, and R2 is a variable grid resistor for tuning. The battery is 140 volts, and the 6.3-volt filament supply may be either a.c. or d.c. A current of about 10 ma should produce a good sine wave at about 1,000 kc with a 6Q5, and at about 550 kc with an 884. This oscillator can be modulated with a crystal phono pickup or microphone connected between grid and cathode, and the modulation should be heard clearly in a nearby radio.

Other applications

What uses can this oscillator be put to? Well, the ionic oscillator will drive an 807 r.f. power amplifier directly. No elaborate modulator circuit is needed for phone operation, as modulation can be applied to the oscillator itself.

The circuit of this transmitter is shown in Fig. 6. Here the ionic oscillator is used as the master oscillator for the 807. (Remember—this is an experiment only and keep F.C.C. regulations in mind!) At 500 kc the power output of the 807 is enough to light a 40-watt fluorescent tube. The bandwidth is no more than 10 kc on any conventional receiver.

The 807 is set up as a conventional class-A amplifier except for the fact that there is no grid tank circuit. The plate tank circuit was designed only to prove a point and not to stand up on any breakdown test. The tank coil was a four-pie 1-mh r.f. choke and the tank capacitor was a midget 144-$\mu\mu$f variable. A 450- to 500-volt d.c. power source supplied the plate and screen voltages, and a dropping resistor supplied the ionic oscillator plate voltage. The ionic oscillator and the r.f. amplifier were coupled through a .05-μf 200-volt capacitor. (This may be varied for optimum drive to the 807; the cut-and-try method will give the best results.)

The ionic oscillator is adjusted till it oscillates best. Then the amplifier is turned on and the plate tank is tuned till the fluorescent tube lights with maximum brilliance when touched to the plate of the 807. Those who know tank circuit design and are licensed to operate on 160 meters or higher frequencies can operate the 807 as a doubler. Those who do not have a license are advised not to try this experiment, as this simple transmitter will radiate quite a distance.

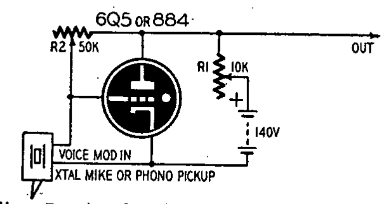


Fig. 5—A circuit for general experimental work with the ionic oscillator.

The ionic oscillator has been used also in audio signal generators, photocell amplifiers, radio receivers, pulse generators, special waveform generators, frequency- and amplitude-modulated oscillators, control circuits, and other special devices.

Other Characteristics

For those who are more interested in the experimental value of the ionic oscillator the following data were recorded during actual experiments:

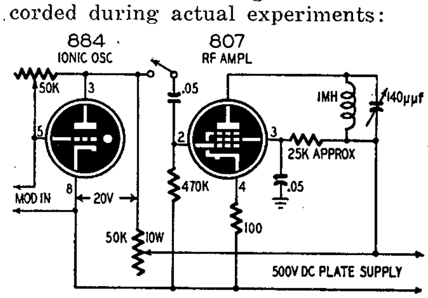


Fig. 6—A 40-watt 500-kc transmitter with an ionic master oscillator. Values are for experimental work only with all precautions taken to prevent radiation in violation of FCC regulations.

It was found that an OC3/VR105 voltage-regulator tube will oscillate at as many as five different modes. These modes can be produced by opening and shutting the plate-current circuit. Each mode will follow the other in sequence as the plate circuit is interrupted. At the same time a spot of blue light can be seen switching up and down the cathode as each mode is reached. These modes or frequencies will always be the same for the same position of the blue cathode spot. This same shifting of frequency can be accomplished by beating one variable-frequency ionic oscillator against another.

It was also noted that if a d.c. or a.c. arc is made on a hard metal surface any ionic oscillator in the vicinity will shift frequency. Arcs on soft metal will not produce this effect. When a Navy type-SN7 stroboscope gas tube is hooked up as an ionic oscillator and placed in the beam of another stroboscopic light source, alternate light and dark bands can be seen moving slowly toward the plate from the cathode. If one pole of a magnet is brought near the column of ionized gas in the SN7 the frequency of this ionic oscillation will decrease as the bands move farther apart.

When an SN7 stroboscope tube is working as an ionic oscillator at about 5,000 cycles, the high-pitched audio note can be heard clearly coming from the tube elements.

If a variable resistor is connected between cathode and grid of a 6Q5 ionic oscillator, the oscillator will continue to work, even after the filament voltage has been removed, when a certain resistance has been reached.

If the grid of a triode-type ionic oscillator is driven very hard by an audio signal generator, the output carrier frequency will increase from about 1,000 kc to 9 mc. There will also be many different waveforms and pulsed radio- or audio-frequency combinations.

A tetrode gas tube such as the 2050 used as an ionic oscillator can have two separate control signals—one applied to the control grid and the other to the screen grid. These two signals can gate the tube to work only when both are present or when one or the other is present. In some tubes fixed a.c. modulating waveforms may be used for switching the ionic oscillations on and off.

In summary, the ionic oscillator is unique in that it is a high-frequency gaseous tube oscillator. In addition, it is a stable oscillator whose frequency and voltage output is constant for wide variations in load impedance. All this is done with extreme simplicity of construction.

Prior to the ionic oscillator, all oscillators using gaseous discharge tubes had the frequency determined by a tuned tank circuit connected to the output of the tube or by the charging time of an external capacitor as in a relaxation oscillator. The upper limit of most gaseous tube oscillators is generally no more than 50 kc because of the off-on process which has a definite minimum time limit. However, the ionized gas in a discharge tube normally oscillates within the tube at a frequency between 500 and 1,500 kc at low orders of ionization, the frequency being dependent on certain of the external circuit constants.

It should be clear to the reader that this is truly a new and unusual electronic invention that has many possibilities. Data will have to be compiled and checked before practical applications can be made. END